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Human mobility intentions in response to heat in urban South East Asia

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ABSTRACT

Climate change and associated weather extremes and natural hazards have large impacts on the urban population of the Global South where population growth will rapidly increase the already large number of people who will be affected. Using Protection Motivation Theory (PMT), we investigate how hot temperatures, manifested as heat stress, is affecting the intentions of moving among the urban population in three Asian countries (Indonesia, Malaysia, Philippines). We conducted an online survey with 2219 respondents. Almost all respondents (98%) had experienced heat stress, albeit at different levels. When asked whether respondents would be likely to move away from their current locations because of heat, nearly a quarter (23%) reported that they were very likely to do so, and 50% that they probably would. Stronger moving intentions because of heat were associated with women and older people. Concerns about increases from damage from heat (threat appraisal) were more strongly associated with moving intentions than an understanding of the costs and benefits (coping appraisal). Among the threat appraisal, heat stress levels and risk perception were the strongest predictors of moving intentions because of heat. The results contrast with the findings of migration studies in response to sudden onset hazards and underpin the differences in adaptation behaviour in response to different climate change impacts. Moving away to cooler places as an adaptation strategy to heat may be challenging to foresee in terms of timing, capabilities, destination and potential costs because it may not happen soon. We strongly recommend further research on climate change migration of the urban population, including within urban and urban-to-urban movements. While many people move back after sudden onset disasters, heat potentially leads to permanent movements given it is likely to be better planned, and as the habitability of some places is increasingly compromised. Overall the effects of slow onset environmental hazards such as pollution and heat on migration warrant more research attention given the rapidity of urban population growth, particularly in the global south.

1. Introduction

Globally human-induced warming reached approximately 1 °C (± 0.2 °C likely range) above pre-industrial levels in 2017 and is likely to reach 1.5 ° between 2030 and 2052 if it continues to increase at the current rate (high confidence; IPCCC, 2018). However, warming greater than the global annual average is already being experienced in many regions and seasons (IPCCC, 2018) and there is currently a 95% chance that global temperatures will increase by more than 2 ° by 2100 (Raftery et al., 2017). To date, around 30% of the world' population already live in areas where the daily mean surface air temperature and relative humidity exceeds deadly thresholds for at least 20 days a year (Mora et al., 2017). Extreme heat events such as heat waves and droughts are also predicted to rise in frequency and severity (Perkins et al., 2012).

Extreme heat adversely affects human health and is increasingly becoming a serious public health issue. Exposure to heat reduces well-being, mental and physical health and sometimes causes death (López-Sánchez and Hancock, 2018) with older people and those with existing illnesses being particularly vulnerable to heat related morbidity and mortality (Gosling et al., 2009; Bakhsh et al., 2018). In the workplace heat can reduce productivity (Zander et al., 2015), raise labour costs (Zhao et al., 2016) and increase the rate of occupational accidents (Xiang et al., 2014).

Urbanization, one of the major challenges of ongoing global change (Krellenberg et al., 2017), interacts strongly with climate change. People in urban areas worldwide are predicted to be twice as affected by heat than people in non-urban areas (Wouters et al., 2017), partly because of the urban heat island (UHI) effect. Those in the rapidly growing cities of South Asia and Africa are particularly vulnerable

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(Matthews et al., 2017). In the Philippines, for example, population density was positively correlated with the share of people very stressed by heat (Zander et al., 2018a).

Community responses to urban heat include modifications to urban design (e.g. air-conditioned shelters, cool pavements and retrofitting of reflective coatings to buildings), changes in land use (e.g. blue and green spaces), public health education and outreach (e.g. targeted warnings, heat wave planning guides) and other public assistance such as air-conditioned transportation (see Wilhelmi and Hayden, 2010). On an individual level, the most common coping strategy is adjustment of clothing including using hats, sunglasses and umbrellas (Bakhsh et al., 2018), hydration, resting (and seeking shade) and cooling (Zander et al., 2018b). Installation of air-conditioning units at home, while too costly for some households, is surging, contributing to the financial burden of many households (Santamouris et al., 2015) and consuming large amounts of energy, adding further to climate change.

Another response to cope with the impacts of environmental and climate change is migration (Hugo, 2011). While in-situ climate change adaptation (Bardsley and Hugo, 2010) is often preferred over migration (e.g. Laurice Jamero et al., 2017; Stojanov et al., 2017), and is sometimes regarded as the last resort for those wealthy enough to afford the move (Black et al., 2011a), there are situations where migration can be the strategy of choice. Climate driven or not, migration can open up opportunities for migrants and their families including income diversification, capacity building and personal development as well as providing remittances for those who stay at home (Black et al., 2011a; Kniveton, 2017). Also, in some places temperatures may be so extreme that it is becoming unsafe to work or spend considerable time outside, making in-situ adaptation increasingly difficult (see Kjellstrom et al., 2017). When people are so stressed by heat that their daily activities are compromised and their well-being and life satisfaction declines, they are likely to cross a mobility threshold (see Bardsley and Hugo, 2010). Such thresholds can also be economic in nature where adapting to the heat becomes too costly and/or labour activity has to be reduced so much that income generation capacity is inadequate.

However, establishing direct causality between environmental and climatic factors and migration is challenging. Many studies have shown mixed results, i.e. direct positive links between these factors and migration could not be established or established for some environmental conditions or hazards but not for others (e.g. Gray and Wise, 2016; Bohra-Mishra et al., 2017; Goldbach, 2017; Nawrotzki and Bakhtsiyarava, 2017; Thiede and Gray, 2017). Environmental factors and climate change is usually just one of many factors informing decisions to move (Hugo, 2011; Adger et al., 2013) alongside traditional drivers of mobility such as family, employment and educational opportunities (see Zelinsky, 1971). There are also many other factors driving human mobility such as digitisation of the economy, better education, higher socio-economic status including income, empowerment of women and changing preferences for lifestyles, as reflected in the expanding literature on environmental and climate change related migration (see Piguet et al., 2018).

Studies which have found a direct link between climate change and mobility mostly concern farming communities (e.g. Bohra-Mishra et al., 2014, 2017; Hunter et al., 2014; Mueller et al., 2014; Cattaneo and Peri, 2016; Thiede and Gray, 2017; Jha et al., 2018). Such communities are often susceptible to the direct impacts of climate change through reduced crop yields or lower livestock productivity (Mendelsohn, 2014; Sultan et al., 2014) allowing a strong link to be established between their rural out-migration and declining viability of their farming businesses and food security (Warner and Afifi, 2014). Much more difficult is to show a link between mobility and environmental and climatic change in societies that do not primarily depend on natural resources, such as urban populations. As it is, while people are escaping the indirect effects of heat on crops and livestock by moving to the cities, they may be putting themselves into conditions that are hotter and more stressful (Zander et al., 2018a).

Research on environmental and climate impacts on the urban populations mostly focuses on health problems from pollution and heat (Hajat et al., 2010). There is very little research on the extent to which health concerns result in migration. As both pollution and heat are slow onset hazards, responses might be expected to be planned and long term rather than driven by swift necessity following disasters (Bohra-Mishra et al., 2017) but the extent to which it currently occurs or is likely to happen appears to be almost unknown. It can be anticipated that heat and pollution would result in migration either to other urban areas that are less polluted or cooler or to less polluted non-urban areas free from the UHI effect. The little research available is consistent with this hypothesis. Pollution was correlated with migration flows in China, with women more likely to move to protect children from harmful effects (Chen et al., 2017), while about 7% of respondents living across Australia (in urban and regional areas) would move to cooler places in response to high heat stress (Zander et al., 2016). However, much more needs to be understood about the heat impacts on urban mobility if appropriate policy is to be developed.

To help fill this significant gap in understanding of the moving intentions of the urban population because of heat we 1) assessed heat stress among the urban population in three south-east Asian countries (Indonesia, Malaysia, Philippines) and 2) investigated how heat stress affected intentions to move as an adaptation strategy. To the best of our knowledge our study is the first to use survey data on perceived heat stress as a reason for migration in the developing world, and among the first anywhere. We explore intentions to move away which will differ from actual mobility behaviour. While the chosen measure is just a proxy for actual future behaviour, there is a positive relationship between intentions and actual behaviour (Fishbein and Ajzen, 2010). The proxy can nevertheless help to understand future decisions to move, in this case because of heat. The results can contribute to the growing appreciation of the effects of environmental change on human migration, as well helping to develop preparedness and adaptation strategies that reduce societal vulnerability to impending increases in heat (Wilhelmi and Hayden, 2010).

2. Methods

2.1. Framework

Our theoretical framework, protection motivation theory (PMT), was first proposed by Rogers (1975, 1983) and revised by Maddux and Rogers (1983). It was originally applied in social and health psychology to explain the effect of health communication in the form of fear appeals (Floyd et al., 2000; Ruiter et al., 2014). It is now a commonly accepted and widely applied theory to clarify how people deal with protection choices, which in the climate change context include adaptation strategies (see, e.g. Grothmann and Patt, 2005; Bender et al., 2007; Bubeck et al., 2013; Koerth et al., 2013; Keshavarz and Karami, 2016). Since heat exposure can harm people's health and well-being, people are assumed to choose their preferred protection / adaptation strategy. As mentioned before, these strategies can involve in-situ change or movement away to cooler places. The PMT has been successfully applied in the context of sudden-onset hazards such as floods (Grothmann and Patt, 2005; Grothmann and Reusswig, 2006; Bubeck et al., 2013), wildfires (Bender et al., 2007) or landslides (Mertens et al., 2018), and to some slow onset hazards such as drought for farming communities (Keshavarz and Karami, 2016) and sea level rise (Koerth et al., 2013). We are not aware of it having been applied to people aiming to protect themselves from the impacts of climate change related heat.

The basic premise of the PMT is that people engage in adaptive behaviour when facing risks through two main cognitive processes: "threat appraisal" and "coping appraisal" (Rogers, 1975). The choice of the strategy depends on seven constructs organized as two pathways linking perceptions to behaviour: the threat appraisal pathway

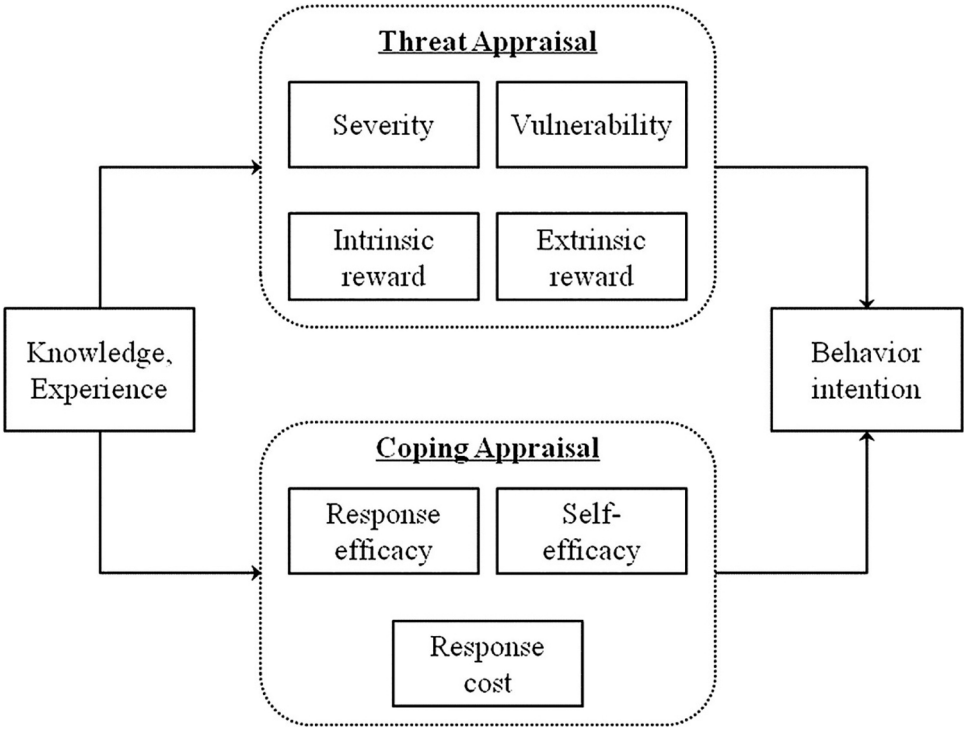

Fig. 1. Protected motivation theory (PMT) and its seven constructs; adopted from Xiao et al. (2014).

encompasses perceptions of the severity of and vulnerability to threats, and the intrinsic and extrinsic rewards received from different behaviours while the coping appraisal pathway includes response efficacy, self-efficacy (an individual's belief in their ability to respond effectively) and response costs. Experience and knowledge as well as socio-economic factors affect both pathways (Fig. 1) and eventually the behaviour performed to protect themselves.

This theory is consistent with the growing interest in using socio-cognitive theories to study risk perception and motivation for adaptation to climate-related risks since knowledge and perceptions can drive behaviour change (Grothmann and Patt, 2005; Abrahamson et al., 2008) and also with the theory of planned behaviour which is widely used in migration studies (Zander et al., 2016; Speelman et al., 2017).

2.2. Data collection and sampling

We used Microworkers to collect the data. Microworkers is an online crowdsourcing platform which offers access to a large number of internationally widespread users (see, e.g. Goodman et al., 2013 and for a discussion). Users can register for free. Crowdsourcing platforms such as Microworkers and Mechanical Turk are increasingly being used to recruit people to complete research surveys, particularly in psychological research (Crone and Williams, 2017; Stewart et al., 2017). We used Microworkers because it claims a large South-East Asian membership (Sulser et al., 2014). We only sampled adult users and started a "Hired Group" campaign by sending letters of invitations to users from Malaysia, Indonesia and the Philippines (the criteria was the country of residence, not the nationality). The invitation letter contained a brief description of the topic, the names and organisation of the researchers and a link to an external online survey (designed in Qualtrics). To minimise selection bias, no indication about the study topic was given in the invitation letter. Respondents received USD 1 for the completion of the survey from MicroWorkers when providing a code which was revealed upon completion. On average, respondents took 19 min to complete the survey. Ethics approval was obtained from the Charles Darwin University Human Research Ethics Committee (H17033).

The campaign was open for eight months, between 22 May 2017 and 21 January 2018. During this period, we constantly updated the group to which the invitation was sent, i.e. new users who signed up with MicroWorkers and who were from one of the three countries. We aimed for 500 valid responses from each country. From Malaysia we received 552 during the survey period (on average of 64 per month) of which we could not use 34 because they were largely incomplete. We received 610 from Indonesia (70 per month) and omitted 46 and from the Philippines we received 1234 and omitted 97. While we received many more responses per month from the Philippines (142, probably because more people from the Philippines had signed up to the crowdsourcing platform than had done so from the other two countries), we wanted all three surveys to cover the same timeframe so did not stop updating the list of new workers. The final sample size was therefore 2219: 514 from Malaysia, 564 from Indonesia and 1137 from the Philippines. The reason the campaign was open for eight months was two-fold: first, we wanted to cover a wide range of temperatures during the survey, avoiding a narrow time horizon during which extreme heat might have occurred and potentially biased the responses; second, responses from Indonesia and Malaysia came in slowly so the target took some time to be reached.

2.3. Questionnaire and variables

The questionnaire consisted of four parts, questions on: 1) perceived heat stress, 2) moving intentions, 3) perceptions towards a range of environmental and social issues, and 4) socio-demographic background (age, gender, education, income, household situation, place of residence, health).

Only by understanding precisely what heat means to those who experience it is it possible to interpret its impact on mobility meaningfully (Parsons, 2018). This is why we aimed to understand the direct impact of heat on people, manifested by their perceived heat stress. Following the approach of Zander et al. (2015), the question on perceived heat stress was posed as follows: *"Do you ever feel stressed by heat in what you are doing?"* Respondents could tick one of the following responses:

i No, never (0)
ii Yes, but rarely (1)
iii Yes, sometimes (2)
iv Yes, often (3)
v Yes, very often (4)

The question to gauge moving intentions because of heat was as follows:

> When you think of all possible reasons for moving or staying where you are, such as employment, family or education, would you move away from your current location of residence because of heat?

Answers were possible on a scale from 1 to 10 with 1 meaning very unlikely to move and 10 very likely to move because of heat.

Understanding respondents' perceptions can explain their likely behaviour change in regard to climate change adaptation (Grothmann and Patt, 2005; Adger et al., 2009). A positive relationship between moving intentions and natural hazard risk perception has been shown, for example, in the case of wildfires (Nawrotzki et al., 2014). We assumed that risk perception about the consequences of increasing heat influences the intention to move. In line with the PMT, we measured two dimensions of risk perception: *Perceived severity* of extreme heat events and *perceived vulnerability* to extreme heat events. Both were measured on a scale from 0 to 100 with 0 no perceived risk and 100 very high risk. As responses were highly correlated (correlation coefficient of 0.81, Fig. S1 in Supplementary Materials) we transformed them into one risk perception index, calculated as the product of both. The resulting variable is referred to as perceived risk perception (see Table 1).

Previous literature points to a complex interplay of factors that influence displacement following natural hazards including those relating to wealth/income, education, age, and gender, with evidence for both increased migration and decreased migration for each of these variables in different settings (Black et al., 2011b). We included those variables as control variables besides those underlying the PTM (Table 1). Education is usually positively associated with migration, since better educated people have more chances to find employment elsewhere (Keshavarz and Karami, 2016). Younger people are also expected to be more likely to migrate, partly for the same reason (e.g. Hunter et al., 2015; Koubi et al., 2016), but the impact of age is less clear (Nawrotzki et al., 2014; Zander et al., 2016). Women have a higher risk perception than men and are expected to be more likely to migrate in response to natural hazards (Hunter et al., 2015; Koubi et al., 2016). Men tend to be more likely to migrate over long distances, women locally (e.g. Mueller et al. 2012). Socio-economic status is an important factor for migration decisions in response to natural hazards as it shapes both vulnerability and capacity to cope and adapt, including access to necessary resources needed to move (Nawrotzki et al., 2014). People with more assets and higher incomes are assumed to be more likely to move in response to natural hazards (e.g. Hunter et al., 2014) while resource poor households are more often 'trapped' (Black et al., 2011a). However, resource-poor people could also be more likely to migrate in response to natural hazards because they are more vulnerable to the impacts (e.g. because of poor housing; Elliott and Pais, 2006) and a greater need to move away. They also have fewer assets to lose and might be more motivated to seek opportunities elsewhere rather than stay (Thiede and Gray, 2017). Along the same line of argument, we also included a dummy variable for having air-conditioning at home. Since using air-conditioning is an effective means for cooling down (Lundgren-Kownacki et al., 2018), we assumed that those having no access to air-conditioning at home would be more strongly motivated to move away because of heat. Finally, because mobile people are also expected to be more likely to move in response to heat (Nawrotzki et al., 2014; Zander et al., 2016), we also included the general intention to move in the next ten years as an explanatory variable.

Table 1
Variables included in the models based on the Protection Theory Motivation (PMT) for all respondents and by country [Indonesia (I), Malaysia (M), Philippines (P)].

Cognitive process	PMT component	Measurement	All	I	M	P
Heat threat appraisal	*Perceived severity (Mean and SD)*	On a scale from 0 to 100, how severe do you think might be the financial damage from extreme heat and heat waves?	40.8 (29.7)	38.8 (27.7)	44.6 (27.5)	40.1 (31.5)
	Perceived vulnerability (Mean and SD)	On a scale from 0 to 100, how likely do you think extreme heat and heat waves will cause financial damage to yourself in the future?	39.1 (29.4)	36.7 (27.5)	43.5 (27.5)	38.2 (30.9)
	Risk perception (Mean and SD)	= Perceived severity * Perceived vulnerability / 1000	23.0 (25.7)	20.0 (22.1)	25.2 (25.2)	23.4 (27.3)
	Experience (Heat stress)	Do you ever feel stressed by heat in what you are doing? ● No, never (0) ● Yes, but rarely (1) ● Yes, sometimes (2) ● Yes, often (3) ● Yes, very often (4)	2.6	2.3	2.6	2.9
Coping / adaptation appraisal	Intrinsic reward	It is important for me to maintain a lifestyle where I can do activities outside without air-conditioning (0/1)	91	87	91	92
	Extrinsic reward 1	Most people I know who live in hot areas intend to move to cooler areas (0/1)	68	66	61	73
	Extrinsic reward 2	I am worried for the next generation because of increasing temperatures and the effects of it (0/1)	93	91	93	96
	Self-efficacy 1	I have usually found it easy to move (0/1)	33	47	29	29
	Self-efficacy 2	I am competent and capable in the activities that are important to me (0/1)	88	87	85	91
	Response efficacy 1	Living in a cooler place enables me to maintain the lifestyle I want (0/1)	80	80	74	84
	Response efficacy 2	Many of my friends and people I care about move frequently (0/1)	51	59	49	48
	Response costs 1	In the last 10 years I moved at least once without financial difficulties (0/1)	34	31	37	35
	Response costs 2	Intending to move oversees (0/1)	8	5	5	11

2.4. Data analyses

For easier interpretation and subsequent analysis, we grouped the answers about intention to move on the scale from 1 to 3 into 'weak intention', 4–7 into 'moderate intention' and 8–10 into 'strong intention' to move away from the current location of residence because of heat. We used a multinomial logit (MNL) model to analyse the determinants of respondents' intention to move because it permits analysis of decisions across more than two categories, allowing the determination of choice probabilities for different categories (Green, 2000). The dependent variable takes on one of the three forms: weak intention to move, moderate intention to move and strong intention to move. The independent variables are socio-economic characteristics of respondents (control variables) and cognitive variables according to the PMT. The parameter estimates of the MNL model provide the direction of the effects of the independent variables on the dependent variable. Because of the different sample sizes from the three countries, the responses were weighted accordingly. Data from Malaysia (518 responses) were weighted by 1, data from Indonesia (564 responses) by 0.92 and data from the Philippines (1137 responses) by 0.46. First, we ran a baseline model with all independent variables that were deemed relevant to mobility decisions (see Tables 1 and 2 for the variables and Table S1 in Supplementary Materials for the results). Secondly, we used the stepwise procedure and selected the best model based on BIC.

For the bivariate analyses we used ANOVA with Tukey post-hoc test or the non-parametric Kruskal-Wallis (KW) test with Dunn's post-hoc test. To analyse the relationship between two categorical variables we used Chi square tests.

3. Results

3.1. Sample characteristics

Respondents average age was 27.9 (SD: 7.4) with no significant differences across the three countries (Table 2). There were significantly fewer female respondents in Indonesia and respondents from Indonesia had also slightly lower education scores (KW = 51.5, df = 2, $p < 0.001$).

3.2. Heat stress

Only 2% of respondents across all three countries reported that they did not feel heat stressed at all in the previous 12 months (the recall period); 11% had rarely felt heat stressed. A third of respondents sometimes felt heat stressed, 28% often and 26% very often. While the 'sometimes' category was most prevalent in Indonesia (39%) and Malaysia (35%), respondents in the Philippines selected the very often heat stressed category more often than the other (34%; Fig. S2 in Supplementary Materials). Average heat stress level (scale between 0 and 4) was 2.6 but varied among countries; respondents from Indonesia were significantly less stressed (KW = 127.6, df = 2, $p < 0.001$; Fig. 2). This could also be because respondents from Indonesia perceived extreme heat events to be a lesser risk than those in Malaysia and the Philippines (F = 5.93, df = 2, p = 0.0027) (see Table 1). Heat perception, in return was positively associated with the level of heat stress (F = 21.35, df = 4, $p < 0.001$). Those very often and often heat stressed had the highest heat risk perception score, followed by those sometimes heat stressed. Those never or rarely heat stressed were least aware of the risk.

In the Philippines and Malaysia, where the gender split of respondents was close to 50:50, female respondents were significantly more heat stressed ($p < 0.001$). We did not detect a gender effect for Indonesia (see Fig. S3 in Supplementary Materials).

Table 2
Sample characteristics.

Characteristics	Overall (N = 2219)	Indonesia (N = 564)	Malaysia (N = 518)	Philippines (N = 1137)
Age (Mean; SD)	27.9 (7.4)	27.8 (7.3)	27.4 (7.7)	28.1 (7.2)
Female (%)	47	28	50	56
Level of education (Median, Mean, SD)	4 (3; 1.0)	3 (3.2; 1.1)	4 (3.4; 0.9)	4 (3.5; 0.9)
Good health (%)	73	80	73	70
Level of income (Median, Mean, SD)	3 (3.6; 2.4)	3 (3.5; 2.4)	3 (3.9; 2.6)	3 (3.5; 2.3)
Air-conditioning at home (%)	50	48	58	46
Intent to move within the next 10 years (%)	78	82	77	76

Level of education on a scale from 1 (primary school) to 7 (post-graduate degree).
Level of income on a scale from 1 to 7, country-specific brackets.
Good health as compared to bad and fair health.

3.3. Intention to move in response to heat

The overall mean of mobility intention was 5.3 (SD: 2.6), on a scale from 1 to 10. There was a slight but significant difference (F = 8.2, df = 2, $p < 0.001$) between the three countries (Fig. S4 in Supplementary Materials) with people in Indonesia (4.9; SD: 2.6) having a lower level of moving intention in response to heat than people in the Philippines (5.5; SD: 2.7). The median was five in each country. Respondents' intentions in Malaysia did (5.3; SD: 2.4) not differ from those in either the Philippines or Indonesia. Many more respondents from the Philippines were very likely (scale 9 or 10: 17%) to move away in response to heat than respondents from the other two countries (Malaysia: 12%; Indonesia: 10%) (Fig. 3). Overall, women (5.7; SD: 2.6) were also more likely to intend to move because of heat (F = 49.9, df = 2, $p = < 0.001$) than men (4.9; SD: 2.6). The gender effect was found in each country with the largest difference across gender in Malaysia (women: 5.8 (SD: 2.4); men: 4.8 (SD: 2.4); F = 22.2; df = 2, $p = < 0.001$) (see Fig. S5 in Supplementary Materials). In the Philippines, the difference, albeit significant, was less pronounced because men were more likely to move than in the other two countries (women: 5.8 (SD: 2.6); men: 5.2 (SD: 2.6); F = 15.0; df = 2, $p = < 0.001$). In Indonesia, where the share of female respondents was only 28%, women were also more likely to intend to move (women: 5.4 (SD: 2.5); men: 4.8 (SD: 2.6); F = 6.9; df = 2; p = 0.009) but there was no difference in the median score (5 for both). Those who confirmed that they intended to move anyway within the next ten years were not also more likely to move because of heat (F = 12.2; df = 2, p = 0.173).

When grouping the responses on the scale from 1 to 10 into the mobility categories used for the subsequent modelling, 27% of respondents had a weak intention (1–3), half a moderate (4–7) and 23% a strong (8–10) intention to move away in response to heat.

3.4. Determinants of moving intentions

As already indicated by the results of the bivariate analysis, women were more likely than men to have a moderate or a strong intention to move (Table 3). Women were 64% more likely to have a strong and 59% more likely to have a medium moving intention because of heat than men. A moderate or strong intention to move also increased with age and a relatively high income was positively associated with strong moving intentions. The other control variables education, health, general intention to move within next ten years and availability of air-conditioning at home (see Table 1) had no significant impact on moving intentions because of heat. There was also no difference across the three countries (see baseline model results in Table S1 in Supplementary Materials).

Of the cognitive (PMT) variables, three had a significant impact on the intention to move: experience of heat stress, perception of risk of

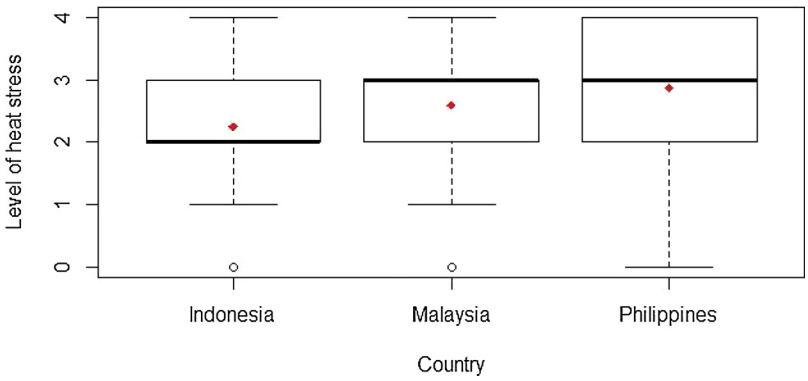

Fig. 2. Differences in stated heat stress levels across respondents from the three study countries.
Note: The dots signify the means.

financial damage and response efficacy. The higher the degree of self-reported heat stress and the degree of risk perception, the higher the likelihood to move. Respondents who agreed that living in a cooler place enables them to maintain their preferred lifestyle were more likely to have a strong intention to move. Self-efficacy, response costs and intrinsic and extrinsic rewards were not significant determinants of the intention to move because of heat.

3.5. Where would people move to?

About a third (32%) of those respondents who intended to move because of heat (moderate or strong intention), did not know where they would go to and another 30% would move within the neighbourhood. Fifteen percent would move within the region, 13% to another region and 11% overseas. The most frequently named overseas destinations were North America (USA and Canada) with 35%, followed by Australia and New Zealand (20%), Europe (12%), Japan (8%), Singapore (6%) and South Korea (5%). The remaining 14% would move to other Asian countries.

The potential destination did not vary with the level of heat stress, nor by age, income or gender. The differences across the countries were significant (X-squared = 63.22, df = 8, p-value < 0.001) with people in the Philippines most likely to move overseas (Fig. S6 in Supplementary Materials). People in Indonesia most often expressed an intention to move to other regions and had the greatest certainty about their potential destination.

4. Discussion

The results of our survey among a sample of the urban populations in Malaysia, Indonesia and Jakarta on moving intentions in response to climate change related heat shows contrasting findings to existing literature in two areas: the demographic characteristics of migration flows from rural to urban farming societies and the migration responses to sudden onset hazards. Both differences have implications for policy.

4.1. Comparison of urban and rural climate-induced mobility

The effect of climate change on human migration is anticipated to be large, amplifying mobility for other reasons, and has warranted much research on farming communities and their past, present and future movements from rural to urban areas. Of concern is how little is known about urban mobility in response to climate change. This is despite of rapid global urbanisation of rural populations. Over half the world's people already live in urban areas (54%), a proportion predicted to increase to two-thirds by 2050 (United Nations, 2014). This is being exacerbated by climate change, especially in areas and households with directly dependent on the natural environment (Warner and Afifi, 2014), even if employment possibilities in origin and destination locations are more influential than changes in temperature and precipitation (Kniveton, 2017). Some research suggests that migration flows because of climate change from urban areas will be lower than those from rural areas (Nawrotzki et al., 2015). Our research suggests that this may not hold true in the future and that the effect of heat on urban mobility is going to be substantial if adaptation is not possible.

In the tropical conurbations we studied, 23% of the respondents

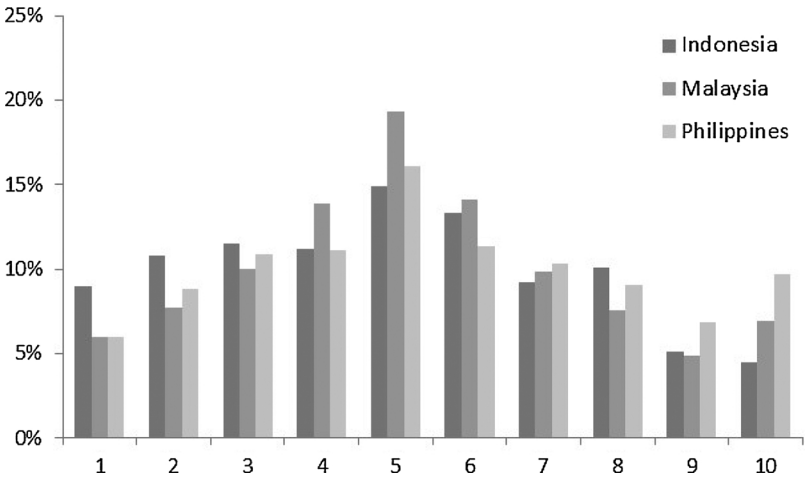

Fig. 3. Respondents' intentions to move away because of heat, measured as responses on a scale from 1 (very unlikely) to 10 (very likely) in three countries.

Table 3
Multinominal logit (MNL) model results (N = 2219), weighted by sample size from each country.

	Moderate intention to move		Strong intention to move	
	Coeff	OR	Coeff	OR
Age	0.020** (0.009)	1.02**	0.026** (0.012)	1.03**
Income	0.032 (0.027)	1.03	0.060* (0.034)	1.06*
Female	0.365*** (0.131)	1.44***	0.567*** (0.170)	1.76***
Response efficacy 1 – Cooler climate enables lifestyle (0/1)	0.050 (0.153)	1.05	0.443** (0.220)	1.56**
Experience with heat stress	0.266*** (0.062)	1.31***	0.421*** (0.084)	1.52***
Risk perception	0.391*** (0.044)	1.48***	0.653*** (0.048)	1.92***
Constant	−1.429*** (0.332)	0.24***	−4.239*** (0.562)	0.01***
AIC	2,813.78			
BIC	2,888.66			

Response efficacy 1: Living in a cooler place enables me to maintain the lifestyle I want (0/1).
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

would be likely to move away and about half would probably move away in response to heat. Such high intentions to migrate are similar to people on islands faced with sea level rise (Speelman et al., 2017), and far higher than suggested by an earlier study from Australia (Zander et al., 2016) where just 7% intended to move because of heat stress (although this was about 50% among young men in physical intense jobs). Our study suggests that the demographic characteristics of heat-induced urban migration will differ from better-studied rural to urban migration currently being exacerbated by climate change and the mobility associated with rapid-onset climate-related threats like floods or storms. It is also likely to exacerbate existing inequities and potentially increase social tensions.

We found that women and older people are more likely to intend to move in response to heat, irrespective of their education. In contrast, global studies have shown that those moving from rural to urban settings as a result of climate change tend to be men (Henry et al., 2004; Warner and Afifi, 2014; Bohra-Mishra et al., 2017) who are young (e.g. Henry et al., 2004; Koubi et al., 2016; Bohra-Mishra et al., 2017) and better educated than their peers (Bohra-Mishra et al., 2017; Jha et al., 2018). Such patterns are also apparent from studies in Indonesia (Bohra-Mishra et al., 2014; Goldbach, 2017; Thiede and Gray, 2017) and the Philippines (Bohra-Mishra et al., 2017). Those moving into cities from rural areas also tend to have high levels of self-efficacy – i.e. they feel confident in their ability to adapt to the new circumstances (Keshavarz and Karami, 2016), another finding that we could not confirm.

Understanding the role of environmental change in the mix of reasons urban people might have for moving is more challenging than for rural populations, since most people in urban areas work inside and are not directly dependent on natural resources. Our paper is thus one of the first to attempt to assess how intentions to move among urban populations are affected by heat. What we found contrasted strongly with the studies of climate-induce rural-urban migration. In our study the people most likely to move because of heat were older and women, with education having no impact that we could detect. The little other research on environmentally-driven migration of urban populations support these findings and are consistent with climate-induced urban migration being driven by risk assessment rather than opportunity. For example, Chen et al. (2017) found that females are more likely than men to migrate in response to air pollution in China, which they interpret as being consistent with families living apart in order to protect young children. Similarly, women in Thailand have been more likely than men to choose migration as a means to reduce risk from tsunamis (Witvorapong et al., 2015), again probably to protect their children from future hazards.

Some of our results may be a result of our sampling strategy. Our online survey might have targeted the people best equipped to move in response to heat. People participating in online surveys have the technological skills and the required hardware, and are likely to be better educated, wealthier and younger than the general population (e.g. Nielsen, 2011; Windle and Rolfe, 2011). Thus, there may not have been sufficient contrast in education levels across the sampled population to detect an influence of education because less educated people were probably less likely to participate. One indication of a potential bias towards education is that completing the survey required at least a rudimentary knowledge of English.

Income was positively correlated with intention to move but the cost of moving (as a coping appraisal) was not seen as a constraint. In the wider population, which would have included the poorest people of the urban population (e.g. slum dwellers) whom could only be reached via personal interview, it can be anticipated that poorer people might have similar desires to move but be more constrained by the expense, and therefore trapped where they are (Black et al., 2011a). Poorer people are also less likely to have the resources necessary to move away (Hunter et al., 2014; Nawrotzki et al., 2014). We did not find evidence that those who have no access to air-conditioning at home, also a sign for socio-economic status, are more likely to move in response to heat. Unlike the direct perceived heat stress, no impact on intentions to move was associated with a higher vulnerability to heat exposure, in contrast to findings for other natural hazards (e.g. Elliott and Pais, 2006).

That our sample of the urban population is also biased against the oldest sector of the population, because they are also less likely to have the computer and English language literacy needed to participate in the survey, makes our detection of a positive relationship with age and intention to move more noteworthy. However, this might explain why we did not find a relationship between health and moving intentions as older people are more likely to suffer health problems caused or exacerbated by heat (Gosling et al., 2009). Older people might be even more likely to intend to move than those we sampled, especially those with compromised health. Of future concern should be the high and increasing rates of diabetes and cardiovascular disease of the aging urban population in Asia (Ramachandran et al., 2012; Ohira and Iso, 2013) which make people more susceptible to heat stress (Ma et al., 2011; Nitschke et al., 2011) and maybe more likely to wish to move to cooler and non-urban areas.

Our results also differ from rural-urban migration study results in that there was no relationship between intentions to move and self-efficacy – those intending to move did not express great confidence in their ability to maintain their quality of life. Our results are instead consistent with a feeling of concern about heat but little idea of what to do about it. A high proportion of people particularly in the Philippines, had recently experienced high levels of heat stress to such an extent that it was second strongest predictor for intention to move – as in other studies (Grothmann and Patt, 2005; Koerth et al., 2013), personal experience strongly influences adaptation behaviour. Respondents moving intentions were associated with fears of future financial damage

arising from increasing heat, as found studies on movements in response to flood threat (e.g. Grothmann and Reusswig, 2006; Bubeck et al., 2013).

4.2. Speed of hazard onset

Our results highlight the greater importance of threat appraisal than coping appraisal in explaining moving intentions. While some studies have concluded that coping appraisal is a better predictor for adaptation behaviour than threat appraisal (e.g. Koerth et al., 2013 for sea level rise), PMT has mostly been applied to sudden onset hazards such as drought (somewhere in between slow and sudden), floods and typhoons (Keshavarz and Karami, 2016; Mertens et al., 2018) which are severe but rare and finite in time; these studies mainly find that coping appraisal is a better predictor for migration than threat appraisal. They are also more likely to affect rural populations because of their impact on natural resource use (Pelling, 2003). Slow impact threats like heat or pollution have their biggest impact on urban populations (Hajat et al., 2010), movements of whom, as noted, have been little studied. Because they are slow there is time to assess the severity of the threat on matters like health, particularly the health of children and older people, whereas sudden onset hazards require rapid appraisal of how to cope with immediate hazards, with those with greatest confidence in their coping ability (high self -efficacy) likely to change their behaviour (van Dalen and Henkens, 2012).

Our results suggest that there is great uncertainty about how to cope with heat even though there is more time either to adapt in-situ or to plan migration in the long-term (Koubi et al., 2016; McLeman, 2018). About a third of respondents had not yet thought about a destination, as was also found in the Maldives (Stojanov et al., 2017). Relatively few (11%) were considering moving abroad in response to heat, and even fewer to a different continent. This corresponds with empirical data that shows that, to date, international migrant flows in response to any form of climate change have been low and that it is internal migration that will be the principal response. Only 13% would move within their countries to a different region where they would presumably experience a different climate. It was surprising that 15% would move within their region and 30% within their neighbourhood (i.e. in the same city). While the topography and the climate might vary within regions, for instance, when moving from the hinterlands to the coast or the hills within the same region, it is unlikely that heat stress can be reduced when moving within the neighbourhood. In some places, cooler 'hill stations', formerly used to escape lowland heat, are now rapidly urbanising as is their UHI effect (Estoque and Murayama, 2016). This shows that moving as adaptation strategy in response to heat might be in peoples' minds, since they feel heat stressed, but actual movements will need more planning, and possibly a more pressing trigger than is currently the case. Unlike in Europe, where some people move to rural areas for lifestyle reasons (e.g. Stockdale and Catney, 2014), many inhabitants of south-east Asian cities will have actively moved away from rural areas, at least some because of climate change, so are likely to be reluctant to reverse that decision. Those who have been born and raised in urban areas will be unlikely to have the desire and social networks to move to rural areas.

4.3. Policy implications

The level of heat stress, as a direct impact or experience of heat, is, together with risk perception, the strongest predictor of movement intention. Also, people who responded that they would like to move somewhere cooler would do so to maintain the lifestyle they want (positive effect of response efficacy). It follows that fewer people would move if heat stress could be relieved. Although air-conditioning sales are rising rapidly, drawing over 50% of peak load in countries like Singapore (International Energy Agency (IEA, 2018), they are not necessarily the whole answer. While they are the most effective means for the cooling of indoor space (Lundgren-Kownacki et al., 2018), they contribute to the UHI effect (de Munck et al., 2013) and, at least in Manila, do not appear to reduce heat stress of people in high density urban environments (see Zander et al., 2018a). Solutions therefore lie in the field of urban planning (see Akbari and Kolokotsa, 2016) and housing design, including retrofitting (Rossi et al., 2015). Caution is needed when making cities climate-smart. Creating public green and blue spaces can lead to gentrification, also already happening in Manila (Choi, 2013) and there is a realisation that modifications to public space need to be 'just green enough' to ameliorate the climate but not so green that poorer households are disadvantaged by rising land and rent prices (Wolch et al., 2014). Policies on urban planning and climate change adaptation also need to be integrated with other policies, particularly those designed to mitigate air pollution, and they must be at all times climate just.

At the same time heat wave warnings and increasing public awareness of how to behave in periods of extreme heat (e.g. right clothing, drinking, resting, cooling, keep curtains closed to block out the sun) can also help to reduce the health effects of heat (Hajat et al., 2010). Heat wave action plans and guidelines already exist for many cities (e.g. Adelaide, Melbourne, Frankfurt (Hessen), Montreal, New York) and countries (e.g. England, France, Italy), but to our knowledge not yet for Jakarta, Manila, Kuala Lumpur or any other large city in the three research countries. In 2013 (following a severe heat wave in 2010), the city of Ahmedabad, in Gujarat State, India, implemented the first 'Heat Action Plan' in South Asia which by now encompasses ten cities across two states in India (NRDC, 2016). Heat-health warning systems need to be in place in every large city, and information about how they work and what to do needs to be disseminated widely.

4.4. Future research needs

Our findings point to the need for more comprehensive research in three areas. First, mobility of megacities in developing countries in general needs to be better understood. South Asian and African cities will be the most exposed to heat over the coming century due to a combination of rapid population growth and an increase in extreme temperatures (Wouters et al., 2017) but there appears to be neither knowledge nor planning of where people might move if stress of living in over-heated cities becomes intolerable.

Second, better data are needed to understand migration (IOM, 2018). Many environmental and climate change migration studies use large datasets (e.g. census data or national household panel surveys) to establish relationships between environmental change and human mobility (e.g. Gray and Mueller, 2012; Mueller et al., 2014; Bohra-Mishra et al., 2014, 2017; Cattaneo and Peri, 2016; Gray and Wise, 2016; Nawrotzki and Bakhtsiyarava, 2017; Thiede and Gray, 2017) but these studies are rarely able to establish causality (Falco et al., 2018). More case studies and primary data collection is needed, on both actual movements of people and intentions to move. Only through direct survey can the puzzling complexity uncovered by panel data analysis (e.g. Gray and Wise, 2016) be understood. Surveys of people who have actually moved would be particularly useful to explore the role of environmental and climate change factors in the decision to move to establish direct causalities. Intention to move data can also detect causalities through appropriate survey questions but intentions will always only be an imperfect proxy for actual movement.

Third, more research is needed on the impacts of other slow onset hazards on urban mobility to determine whether there are patterns in response. Despite long-standing beliefs that avoiding heat through seasonal migration had health benefits (Beattie, 2012), there are anecdotal reports of links between asthma and emigration from cities (Chandran, 2017) and there appears to be only one systematic study linking pollution to urban mobility (Chen et al., 2017). Yet, increasing heat and pollution will affect the health of the aging Asian urban population the most who also have to endure the challenges of inadequate

housing and traffic. Our work seems to be the only study probing responses to rising temperatures and increasing heat wave frequency as a slow onset hazard. Insights about the relationship between intention to respond to slow onset hazards and realised actions will be particularly valuable for designing policy.

4.5. Study limitations

Our research explores whether mobility of urban populations is likely to adopted by significant numbers of people as city temperatures rise. As noted, we have not tried to sample the entire population randomly and have therefore refrained from extrapolating the results to the whole population. There are three reasons why our results needed to be interpreted cautiously – we used online surveys, we used self-assessments and we inquired about intentions to move rather than ascertaining actual movements.

Online surveys often deliver the same results as other survey modes (e.g. Nielsen, 2011; Windle and Rolfe, 2011) and are increasingly employed in social studies as a cost-effective means of data collection. However, bias inevitably remains. We have noticed that our sample is biased towards the younger and better educated people most likely to participate in online surveys (Nielsen et al. 2011; Windle and Rolfe, 2011). Although increasingly being used in academia, obtaining survey participants through crowdsourcing platforms is a relatively new approach. Studies that have explored how samples obtained from conventional online surveys (through research companies) differ to those recruited through crowdsourcing found no difference (e.g. Goodman et al., 2013; Crone and Williams, 2017). Our results therefore overrepresent younger, better educated and technologically-skilled people and inferences to the national populations of the three countries should be made with caution. Also, our sample from Indonesia was not representative of the urban population in terms of gender with women under-represented. However, with improving education and increasing urbanisation, the young urban population will become even more relevant in South East Asian emerging countries and we are therefore confident, that we reached an important sub-section of the national populations.

Second self-reported responses are subject to recall bias, especially because the respondents were asked about their perceived heat stress levels over a period of 12 months. Respondents may also have different interpretations of the heat stress categories. However, self-assessed health is regarded as the most informative health measure in population studies (e.g. Jylhä, 2009) self-reporting has been used and validated in other studies of heat (Schuster et al., 2017; Zander et al., 2015, 2018a& b).

Third, while we could only explore people's intentions to move away and not their actual moves, there is a positive relationship between intentions and actual behaviour (Fishbein and Ajzen, 2010). Furthermore, work on other reasons for migration has shown that behavioural intentions are valid and reliable, so they are commonly used as proxies for actual behaviour (Rise et al., 2003; Fishbein and Ajzen, 2010). Even if the proportion of people actually moving is lower than we found, the surveys are indicative of a level of concern about heat that people seriously consider moving as an adaptation strategy.

5. Conclusions

This paper contributes to the emerging discourse on migration as a form of adaptation to climate change based on empirical studies in three Asian countries. About 77% of a sample of the urban population in three South East Asian countries have a strong or moderate intention to move because of heat, mostly because they already feel stressed by heat, and our sampling strategy may have under-estimated total numbers. Many people have already contemplated where they are going to move to even though they are unsure whether they will cope effectively. There has been almost no research on this impending movement, and there is no policy or planning to mitigate its impact. Instead research has concentrated on the effects of environmental change accelerating existing trends in rural to urban migration. This type of movement is not analogous to people wishing to emigrate from over-heated cities. We found that women, older people and those with high income had the strongest intentions to move. Rural to urban migration, whether because of climate change or not, is primarily undertaken by young men seeking economic advantage. The environmental hazards facing rural communities are also differ in nature and in approaches to risk management. Most rural people return after floods, earthquakes or other rapid-onset environmental hazards. Heat is a slow onset hazard and respondents seemed to be planning their response well in advance. As a result, heat stress may soon become a major driver of planned and permanent migration with substantial economic, social and environmental consequences.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.gloenvcha.2019.03.004.

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